PhytoKeys

PhytoKeys 254: 151–159 (2025)
DOI: 10.3897/phytokeys.254.141498

Research Article

Resolving a nearly 95-year-old enigma: Transfer of the little-known Japanese moss *Arctoa schistioides* to *Kiaeria falcata* (Rhabdoweisiaceae, Bryophyta)

Wen-Zhuan Huang[1], Jia-Yi Zheng[1], Xin-Rui Xia[1], Xin-Yin Ma[1], Tian-Xiong Zheng[2], Yu-Huan Wu[1]

1 *College of Life and Environmental Sciences, Hangzhou Normal University, Hangzhou 311121, China*
2 *Hattori Botanical Laboratory, Obi 6-1-26, Nichinan, Miyazaki 889-2535, Japan*
Corresponding authors: Tian-Xiong Zheng (txzheng@hattorilab.org); Yu-Huan Wu (yuhuanwu@hznu.edu.cn)

Abstract

Taxonomic uncertainties regarding rare species often impede effective biodiversity conservation. One such taxonomic uncertainty is the 95-year-old mystery surrounding *Arctoa schistioides* (Broth. ex Ihsiba) Ihsiba. Since its initial publication in 1929, this species has not been subjected to any further discoveries and is, thus, classified as "doubtful taxa" or "insufficiently known taxa" to date. Assessing the taxonomic status of this species is essential for determining whether a conservation strategy should be implemented. In this study, we examined the holotype of *A. schistioides* and treated this species as a new synonym of *Kiaeria falcata* (Hedw.) I.Hagen, a widely distributed species in the Northern Hemisphere, by providing detailed description, illustration and taxonomic notes. Our findings not only resolve this long-standing mystery, but also enhance our understanding of Japanese mosses and the global distribution of bryophytes.

Key words: Bryophyta, *Dicranum schistioides*, doubtful species, new synonym, taxonomy

OPEN ACCESS

Academic editor: Matt von Konrat
Received: 11 November 2024
Accepted: 6 March 2025
Published: 28 March 2025

Citation: Huang W-Z, Zheng J-Y, Xia X-R, Ma X-Y, Zheng T-X, Wu Y-H (2025) Resolving a nearly 95-year-old enigma: Transfer of the little-known Japanese moss *Arctoa schistioides* to *Kiaeria falcata* (Rhabdoweisiaceae, Bryophyta). PhytoKeys 254: 151–159. https://doi.org/10.3897/phytokeys.254.141498

Copyright: © Wen-Zhuan Huang et al. This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Introduction

Japan is renowned for its extensive diversity of mosses and is regarded as one of the global centres of moss diversity (Geffert et al. 2013). In the most recent checklist, Suzuki (2016) documented 1,270 species across 342 genera within the Japanese moss flora; however, 149 species were classified as "doubtful taxa" in this checklist. Resolving the uncertainties surrounding these questionable species is crucial for enhancing our understanding of Japanese moss diversity and the global distribution of bryophytes.

Arctoa schistioides (Broth ex Ihsiba) Ihsiba is one such enigmatic species, possessing a noteworthy taxonomic history. In 1907, S. Okamura collected an interesting specimen from Mt. Iwaki, Japan (Fig. 1), which was initially identified by V.F. Brotherus as a new species and later compiled and published by Ihsiba (1929) as "*Dicranum schistioides* Broth. ex Ihsiba". Subsequently, Ihsiba (1932) transferred this name to *Aratoa schistioides*. Sakurai (1954) provided a comprehensive catalogue on Japanese mosses, but did not recognise the species. Iwatsuki and Noguchi (1973) listed all genera and species of mosses in Japan and considered

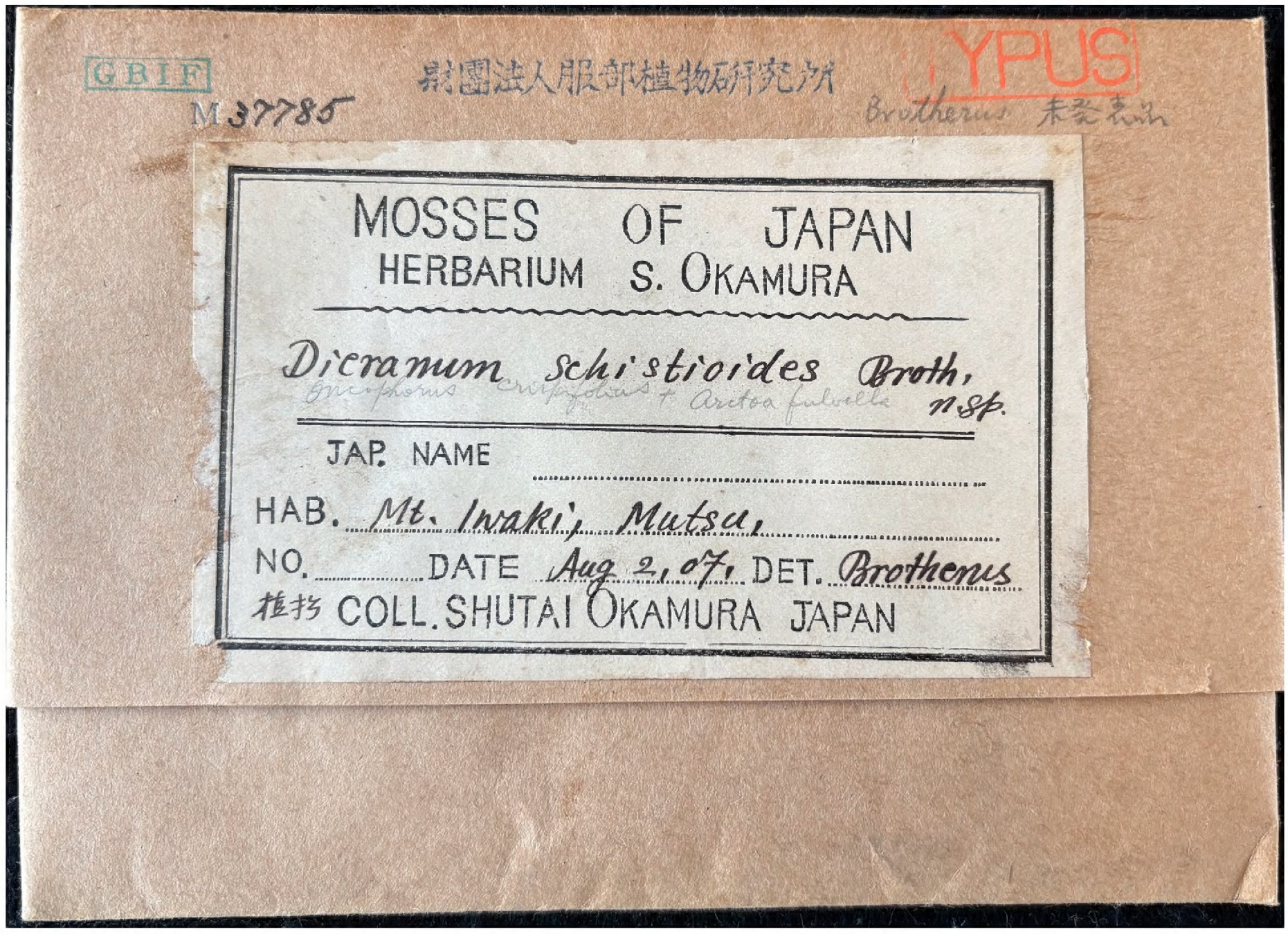

Figure 1. Specimen label of the holotype of *Arctoa schistioides* (Broth. ex Ihsiba) Ihsiba (*S. Okamura s.n.* [NICH 37785]).

A. schistioides a well-established taxon, which was followed by Sekine (1982). Since then, the taxonomic status of *A. schistioides* started to be questioned. Crosby et al. (1999) classified this name as "insufficiently known" in "A Checklist of the Mosses". In subsequent versions of the Japanese moss checklist (e.g. Iwatsuki (2004, 2011); Suzuki (2016)), the distribution and record of *A. schistioides* in Japan was considered doubtful. In fact, this species has not been subjected to any additional discoveries or descriptions in the 95 years since its publication (Ihsiba 1929), resulting in very limited knowledge about it. To date, the status of *A. schistioides* remains an enigmatic issue requiring further resolution.

Accurate species identification is crucial for biodiversity conservation, particularly amongst rare taxa that are taxonomically uncertain due to insufficient study (Ding et al. 2018; Li et al. 2023). Erroneous classification and misidentification may overlook endangered species that warrant protection (Gibson et al. 2019). Conversely, management actions stemming from incorrect species identification can waste resources and funding (Solow et al. 2011). Therefore, further assessment is necessary to clarify the taxonomic status of *Arctoa schistioides*.

Material and methods

Specimen of *Arctoa schistioides* (≡ *Dicranum schistioides*), probably the holotype (*S. Okamura s.n.*; NICH 37785), was borrowed from NICH and morphologically examined. Notes on the nomenclatural status and collection site of this specimen were provided below.

The specimen was examined by using a stereomicroscope (Leica EZ4; Leica, Wetzlar, Germany) and a compound microscope (Leica DM6 B; Leica, Wetzlar, Germany). Microscopic pictures were captured using a digital camera (Leica DFC450 C; Leica, Wetzlar, Germany) attached to the compound microscope. The plant pictures were taken using a stereomicroscope (Keyence VHX-6000; Keyence, Osaka, Japan).

Results

Based on morphological observations, *Arctoa schistioides* exhibits no morphological differences from *Kiaeria falcata* (Hedw.) I.Hagen. Therefore, we treat *A. schistioides* as a new synonym of *K. falcata*.

Taxonomic treatment

***Kiaeria falcata* (Hedw.) I.Hagen, Kongel. Norske Vidensk. Selsk. Skr. (Trondheim) 1914(1): 112. 1915.**

= *Arctoa schistioides* (Broth. ex Ihsiba) Ihsiba, Classif. Mosses Japan: 130. 1932. syn. nov.
≡ *Dicranum schistioides* Broth. ex Ihsiba, Cat. Mosses Japan: 43. 1929.

Type. Japan • Aomori Prefecture, Hiromae City, Mt. Iwaki, 2 Aug 1907, *S. Okamura s.n.* (***holotype*:** NICH 37785!), (Figs 2, 3).

Description. Plants small, in loose tufts. Stems 5–8 mm, simple, cross-section of stem rounded to oval, diameter 0.11–0.15 mm, central strand present. Leaves homomallous, falcate-secund when dry, erect-spreading when moist. Leaves lanceolate at base, gradually tapering into a channelled acumen; costa excurrent as an awn, mamillose dorsally, in transverse section with differentiated guide cells, with dorsal and ventral epidermis and few substereids on dorsal side of guide cells or poorly differentiated; margins plane or slightly incurved distally, entire or crenulate in distal part of acumen; lamina unistratose, occasionally partially 2-stratose in distal portion, margins 1-stratose; distal and median laminal cells short rectangular to subquadrate, with moderately thickened walls, (6–)8–15(–19) × 4–8 μm; basal juxtacostal cells elongate-rectangular, moderately thick-walled, non-porose, 30–50 × 5–9 μm; alar cells gradually enlarged, not sharply differentiated, unistratose, scarcely inflated, composed of short-rectangular to quadrate inflated cells, non-porose, 24–45 × 14–20 μm.

Autoecious. Perigonia terminal closely located below the perichaetia. Perigonial leaves small, ovate-lanceolate to triangular, 0.65–0.75 × 0.45–0.55 mm, costa present or absent; Perichaetial leaves with sheathing base, abruptly into a channelled acumen. ca. 3.2 mm long. Sporophyte single in perichaetium. Seta straight, 5.5–7.5 mm long, yellowish-brown. Capsules obovate, curved and strumose, smooth when dry; Exothecial cells irregular, short rectangle, thick walled; Calyptra not seen; Operculum not seen; Annulus persistent, one row of small cells; Peristome teeth to 0.35 mm long, orange-brownish below, whitish in distal portion, divided into two prongs to the middle, vertically pitted-striolate below, papillose above. Spores 14–17 μm.

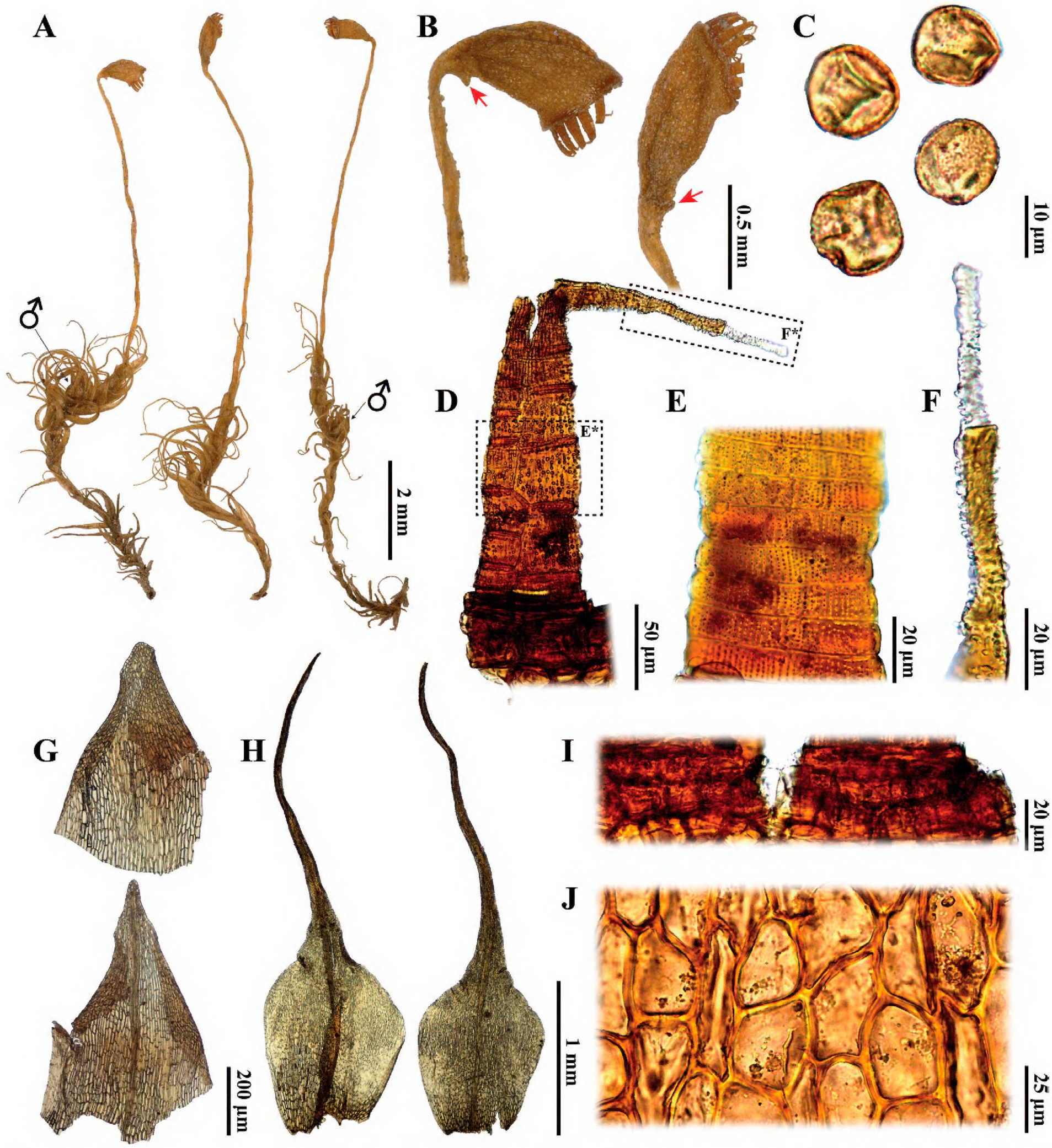

Figure 2. *Arctoa schistioides* (Broth. ex Ihsiba) Ihsiba **A** plants **B** capsules, arrows shows strumose **C** spores **D, E, F** peristome teeth **G** perigonial leaves **H** perichaetial leaves **I** annulus **J** exothecial cells. All from the holotype (*S. Okamura s.n.* [NICH 37785]).

Notes. The nomenclatural status of the cited specimen (*S. Okamura s.n.*; NICH 37785) should be stated first. According to the protologue of *Dicranum schistioides* (Ihsiba 1929), the type specimen of this species was collected from "津軽富士" (Tsugarufuji; in English), which is another name for Mt. Iwaki (岩木山; in Japanese) in Aomori Prefecture, Japan (Tokuhisa 1978). During this study, we extensively searched the bryological collection of NICH and located only one specimen of *D. schistioides*, namely "*S. Okamura s.n.*" (NICH 37785), which was detected by V. F. Brotherus and collected by S. Okamura from

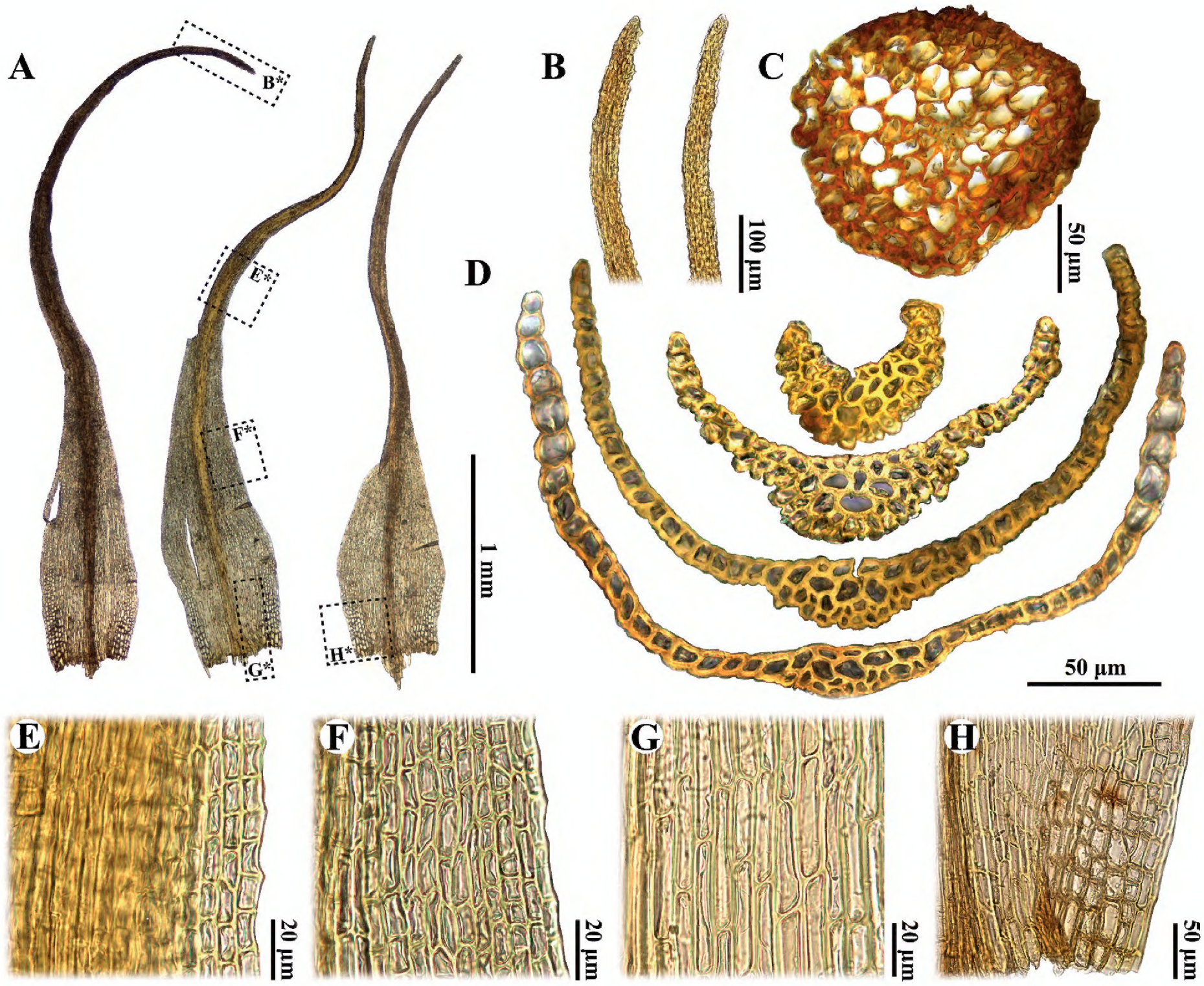

Figure 3. *Arctoa schistioides* (Broth. ex Ihsiba) Ihsiba **A** leaves **B** apex **C** cross section of stem **D** cross sections of leaf **E** upper laminal cells of leaf **F** middle laminal cells of leaf **G** basal juxtacostal cells **H** alar cells. All from the holotype (*S. Okamura s.n.* [NICH 37785]).

"Mt. Iwaki, Mutsu" (Fig. 1). Since Aomori Prefecture was administratively part of "Mutsu" (Sanseidohenshuusho 1975), we thus deemed that this specimen shares the same collection site as recorded in the protologue of *D. schistioides* (Ihsiba 1929). Furthermore, as the original collection of S. Okamura was supposedly deposited in NICH (Vitt et al. 1985), it can be thus inferred that the present specimen is the holotype of *D. schistioides* (Art. 9.1; Turland et al. 2018). As Mt. Iwaki (Fig. 1) is now included in Hiromae City, Aomori Prefecture, we provided a corrected type citation above.

In addition, nomenclature of *Dicranum schistioides* also needs a brief discussion here. This species is nomenclaturally valid although it was only described in Japanese at the time of publication (Art. 39.1; Turland et al. 2018). Later, it was transferred to the genus *Arctoa* without providing a basionym or replaced synonym (Ihsiba 1932). However, the taxonomic authority of its basionym "(Broth.)" and Japanese name "たかねかもじごけ" were clearly given, which should be regarded as an indirect reference (Arts. 38. 14 & 41.3; Turland et al. 2018), giving *A. schistioides* a valid taxonomic status.

Arctoa schistioides is distinguished by the following characteristics: (1) a strumose capsule (Fig. 2A, B), (2) a smooth capsule when dry (Fig. 2B); (3) the

presence of a central strand (Fig. 3C), (4) gradually enlarged alar cells (Fig. 3A, H), (5) a nearly homogeneous costa structure without stereids (Fig. 3D), (6) mamillose leaf subula (Fig. 3B, D), (7) distal laminal cells that are subquadrate to short rectangular (Fig. 3E), (8) elongate-rectangular basal juxtacostal cells (Fig. 3G), (9) a persistent annulus comprised of small cells (Fig. 2I), (10) perigonia located just below the perichaetia (Fig. 2A) and (11) irregular, short rectangle, thick-walled exothecial cells (Fig. 2J). These characteristics imply that *A. schistioides* actually belongs to *Kiaeria falcata* due to the lack of distinct morphological differences between the two species (Newmaster 2007a; Brugués and Ruiz 2012; Lüth 2019).

Morphologically, *Arctoa schistioides* may be confused with *A. fulvella* (Dicks.) Bruch & Schimp. due to their similar plant morphology and leaf shape (Noguchi 1987; Newmaster 2007a, 2007b; Lüth 2019). However, the alar cells of *A. schistioides* are gradually enlarged and not sharply differentiated (Fig. 3A, H), whereas those of *A. fulvella* are clearly delimited and well differentiated (Noguchi 1987; Gao et al. 1999; Ochyra and Buck 2003; Newmaster 2007b; Lüth 2019). Additionally, these two species can be distinguished by their capsule morphology: *A. schistioides* exhibits smooth capsules when dry, characterised by a distinct strumose (Fig. 2A, B). In contrast, *A. fulvella* possesses distinctly ribbed capsules when dry and lacks a strumose structure (Noguchi 1987; Ochyra and Buck 2003; Newmaster 2007b; Lüth 2019). Notably, both species share peristome teeth that are divided into two prongs at the mid-point (Fig. 2D; Noguchi (1987); Newmaster (2007b)); however, this division is not always conspicuous in *A. fulvella*, as the teeth occasionally appear undivided and perforated near the middle (Gao et al. 1999; Ochyra and Buck 2003; Lüth 2019).

Arctoa schistioides is easily confused with *A. blyttii* (Bruch & Schimp.) Loeske. However, the leaves of *A. schistioides* are homomallous and falcate-secund when dry (Fig. 2A), while those of *A. blyttii* are erect-spreading and flexuose (Newmaster 2007a; Brugués and Ruiz 2012). Additionally, the perigonia of *A. schistioides* are situated just below the perichaetia (Fig. 2A), whereas those of *A. blyttii* are terminal on a separate branch or positioned far below the perichaetia (Newmaster 2007a; Brugués and Ruiz 2012). Another distinguishing feature is that the exothecial cells of *A. schistioides* are irregular, short rectangular and thick-walled (Fig. 2J), while those of *A. blyttii* are rectangular and thin-walled (Brugués and Ruiz 2012). Furthermore, the annulus of *A. schistioides* is persistent and consists of a single row of small cells (Fig. 2I), whereas the annulus of *A. blyttii* is deciduous and composed of three rows of large cells (Brugués and Ruiz 2012, 2015).

Arctoa schistioides is also morphologically similar to *A. starkei* (F. Weber & D. Mohr) Loeske and *A. glacialis* (Berggr.) Fedosov, Jan Kučera & M. Stech. However, the upper laminal cells of the latter two species are long and rectangular and their capsules are ribbed or grooved when dry (Newmaster 2007a). In contrast, the upper-middle cells of *A. schistioides* are short rectangular to subquadrate (Fig. 3E) and its capsules are smooth when dry (Fig. 2A, B). Additionally, *Kiaeria falcata* var. *serratifolia* Sakurai, a taxon endemic to Japan, can only be distinguished from *A. schistioides* by its serrate leaf margins (Sakurai 1952), whereas the latter species are smooth or crenulate leaf margins in the distal part of the acumen (Fig. 3A, B).

Dicranum hakkodense Cardot, an intriguing species that shares the Japanese name "タカネカモジゴケ" with *Arctoa schistioides*, but can be distinguished from the latter species by several characteristics. The leaf tips of *D. hakkodense* are moderately fragile and the leaves are straight or only slightly falcate-secund when dry (Ignatova and Fedosov 2008; Huang et al. 2023, 2024). In contrast, the leaf tips of *A. schistioides* are robust, the leaves are homomallous and falcate-secund when dry (Fig. 2A). Furthermore, *D. hakkodense* exhibits clearly differentiated alar cells, a cross section of the costa that contains distinct stereids and a capsule that lacks strumose features (Ignatova and Fedosov 2008; Huang et al. 2023, 2024). Conversely, *A. schistioides* possesses alar cells that are not sharply differentiated (Fig. 3A, H), a cross section of the costa that lacks stereids (Fig. 3D) and a capsule that exhibits strumose features (Fig. 2A, B).

In conclusion, we propose *Arctoa schistioides* as a new synonym of *Kiaeria falcata*.

Acknowledgements

We are grateful to the staff of NICH for searching necessary specimens.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

This research was funded by National Natural Science Foundation of China, grant number 32270215 and Grant-in-Aid for Scientific Research (Specially Designated Research Promotion) of the Japan Society for the Promotion of Science (JSPS).

Author contributions

Wen-Zhuan Huang conceived the study. Wen-Zhuan Huang and Tian-Xiong Zheng wrote the original draft. Jia-Yi Zheng, Xin-Rui Xia and Xin-Yin Ma took the photomicrographs and conducted the measurements of morphological characters. Wen-Zhuan Huang, Tian-Xiong Zheng and Yu-Huan Wu reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Author ORCIDs

Wen-Zhuan Huang https://orcid.org/0000-0001-5871-5699
Jia-Yi Zheng https://orcid.org/0009-0000-6222-8818
Xin-Rui Xia https://orcid.org/0009-0006-7708-7716
Xin-Yin Ma https://orcid.org/0000-0003-0876-4497
Tian-Xiong Zheng https://orcid.org/0000-0002-1963-2302
Yu-Huan Wu https://orcid.org/0000-0002-8139-2194

Data availability

All of the data that support the findings of this study are available in the main text.

References

Brugués M, Ruiz E (2012) The genus *Kiaeria* in Spain, including *K. blyttii* (Bruch et Schimp.) Broth. new to Spain. Cryptogamie. Bryologie 33(3): 263–266. https://doi.org/10.7872/cryb.v33.iss3.2012.263

Brugués M, Ruiz E (2015) *Kiaeria* I. Hagen. In: Brugués M, Guerra J (Eds) Flora Briofítica Ibérica Volumen II. Universidad e Murcia, Murcia, 69–72.

Crosby MR, Magill RE, Allen B, He S (1999) A Checklist of Mosses. Missouri Botanical Garden, St. Louis, 1–315.

Ding X, Xiao JH, Li L, Conran JG, Li J (2018) Congruent species delimitation of two controversial gold-thread nanmu tree species based on morphological and restriction site-associated DNA sequencing data. Journal of Systematics and Evolution 57(3): 234–246. https://doi.org/10.1111/jse.12433

Gao C, Vitt DH, He S (1999) Dicranaceae. In: Gao C, Crosby MR, He S (Eds) Moss Flora of China Vol. 1. Sphagnaceae–Leucobryaceae. Science Press, Beijing & Missouri Botanical Garden, St. Louis, 91–241.

Geffert JL, Frahm JP, Barthlott W, Mutke J (2013) Global moss diversity: Spatial and taxonomic patterns of species richness. Journal of Bryology 35(1): 1–11. https://doi.org/10.1179/1743282012Y.0000000038

Gibson KJ, Streich MK, Topping TS, Stunz GW (2019) Utility of citizen science data: A case study in land-based shark fishing. PLoS ONE 14(12): e0226782. https://doi.org/10.1371/journal.pone.0226782

Huang WZ, Xu H, Ma XY, Zhu RL (2023) *Dicranum hengduanensis* (Dicranaceae, Bryophyta), a new species with fragile leaves from the Hengduan Mountains in China. The Bryologist 126(2): 226–235. https://doi.org/10.1639/0007-2745-126.2.226

Huang WZ, Shen C, Xu H, Shu L, Sulayman M, Wu YH, Zhu RL (2024) A synopsis of *Dicranum* Hedw. (Dicranaceae, Bryophyta) in China, with special references to four species newly reported and re-evaluation of *Dicranum psathyrum* Klazenga. Plants 13(13): 1957. https://doi.org/10.3390/plants13131759

Ignatova EA, Fedosov VE (2008) Species of *Dicranum* (Dicranaceae, Bryophyta) with fragile leaves in Russia. Arctoa 17(1): 63–83. https://doi.org/10.15298/arctoa.17.05

Ihsiba E (1929) Catalog of mosses of Japan. Nishigahara Kankokai, Tokyo, 1–295.

Ihsiba E (1932) Classification of mosses of Japan. Nishigahara Kankokai, Tokyo, 1–176.

Iwatsuki Z (2004) New catalog of the mosses of Japan. The Journal of the Hattori Botanical Laboratory 96: 1–182. https://doi.org/10.18968/jhbl.96.0_1

Iwatsuki Z (2011) A list of Japanese names of mosses. Part II. Hattoria 2: 47–115. https://doi.org/10.18968/hattoria.2.0_47

Iwatsuki Z, Noguchi A (1973) Index Muscorum Japonicarum. The Journal of the Hattori Botanical Laboratory 37: 299–418. https://doi.org/10.18968/jhbl.37.0_299

Li DQ, Lu J, Liang H, Zhu DH, Fan DM, Kou YX, Yang Y, Zhang ZY (2023) The rare *Fagus chienii* is conspecific with *F. hayatae* based on molecular and morphological evidence. Plant Diversity 45(5): 544–551. https://doi.org/10.1016/j.pld.2023.01.003

Lüth M (2019) Mosses of Europe – A Photographic Flora. Michael Lüth, Freiburg, 1–1306.

Newmaster SG (2007a) *Kiaeria* I. Hagen. In: Flora of North America Editorial Committee (Eds) Flora of North America. Volume 27. Bryophyta, part 1. Oxford University Press, Oxford, 420–423.

Newmaster SG (2007b) *Arctoa* Bruch & Schimper. In: Flora of North America Editorial Committee (Eds) Flora of North America. Vol. 27. Bryophyta, part 1. Oxford University Press, Oxford, 362–363.

Noguchi A (1987) Illustrated Moss Flora of Japan. The Hattoria Botanical Laboratory, Hiroshima, 1–242.

Ochyra R, Buck WR (2003) *Arctoa fulvella*, new to Tierra del Fuego, with notes on trans-American bipolar bryogeography. The Bryologist 106(4): 532–538. https://doi.org/10.1639/0007-2745(2003)106[532:AFNTTD]2.0.CO;2

Sakurai K (1952) Observations of the genus *Kiaeria*, *Paraleucobryum*, *Orthodicranum*, and *Dicranoloma* in Japan. Botanical Magazine Tokyo 65(771–772): 251–256. https://doi.org/10.15281/jplantres1887.65.251

Sakurai K (1954) Muscologia Japonica. Iwanami Shoten, Tokyo.

Sanseidohenshuusho (1975) Konsaisu Chimei Jiten. Sanseido Press, Tokyo.

Sekine Y (1982) Nihon san Senrui no Kensaku. Houjou Shokan, Tokyo.

Solow A, Smith W, Burgman M, Bout T, Wintle B, Roberts D (2011) Uncertain sightings and the extinction of the ivory-Billed woodpecker. Conservation Biology 26(1): 180–184. https://doi.org/10.1111/j.1523-1739.2011.01743.x

Suzuki T (2016) A revised new catalog of the mosses of Japan. Hattoria 7: 9–223. https://doi.org/10.18968/hattoria.7.0_9

Tokuhisa T (1978) Konsaisu Nippon Sanmei Jiten. Sanseido Press, Tokyo.

Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Kusber WH, Li DZ, Marhold K, May TW, McNeill J, Monro AM, Prado J, Price MJ, Smith GF (2018) International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. Regnum Vegetabile 159. Koeltz Botanical Books, Glashütten. https://doi.org/10.12705/Code.2018

Vitt DH, Gradstein SR, Iwatsuki Z (1985) Compendium of Bryology. A World Listing of Herbaria, Collectors, Bryologists, and Current Research. Verlag von J. Cramer, Braunschweig.